Overview of NASA Scatterometers Projects

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Abstract - NASA has a long-term commitment to ocean wind remote sensing, starting from SEASAT-A Satellite Scatterometer (SASS), through NASA Scatterometer (NSCAT), to SEAWINDS. The purpose of this paper is to first present the evolution of this overall scatterometer program and the future direction. We will then present an overview of the end-to-end system design, key system parameters, system performance, current status, and the operational timeline of NSCAT. Finally, a summary of the SeaWinds system design, key parameters, and expected performance is presented.

I. INTRODUCTION

Satellite wind scatterometers are microwave radar instruments designed specifically to measure near-surface wind velocity (both speed and direction) over the global oceans. Wind stress is the single largest source of momentum to the upper ocean, driving oceanic motions on scales ranging from surface waves to basin-wide current systems. Winds over the ocean modulate the air-sea fluxes of heat, moisture, gases and particulate, regulating the crucial coupling between atmosphere and ocean that establishes and maintains global and regional climate. Measurements of surface wind velocity can be assimilated into regional and global numerical weather models, improving our ability to predict future weather.

The Seasat-A Satellite Scatterometer [1] operating from June to October 1978 was the first spaceborne scatterometer demonstrating that accurate wind velocity measurements could be made from space. A single-swath scatterometer operating at C-band is presently flying on the European Space Agency's Remote Sensing Satellite mission. As being planned for launched as part of the Japanese Advanced Earth Observation System (ADEOS-1) mission in 1996, NSCAT [2] will be the first dual-swath, Ku-band scatterometer to fly since Seasat. Follow on to the NSCAT is the SeaWinds scatterometer to be launched on the second ADEOS mission in 1999.

II. NSCAT DEVELOPMENT STATUS

NSCAT is a specialized microwave radar instrument designed to provide frequent and accurate measurements of near-surface wind velocity over the global oceans. Like its predecessor on the Seasat satellite, NSCAT uses an array of antennas that radiate microwave pulses at a frequency of 14 GHz and measured the echo power. The radar equation is then used to calculate the normalized

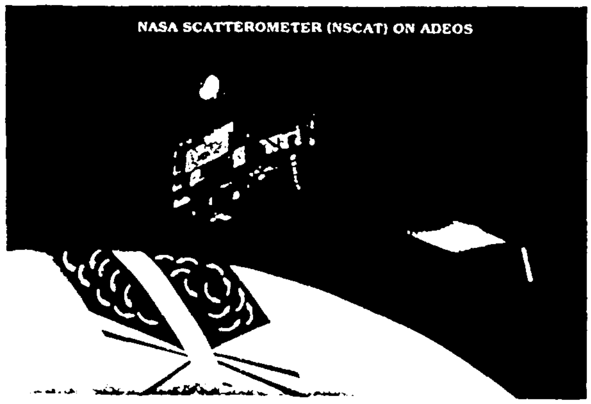

Figure 1. NASA Scatterometer

radar cross-section σ_0 of the wind-driven ocean surface at several look angles. A wind retrieval algorithm is used to retrieve the wind speed and direction over the ocean surface using an empirical geophysical model function. The accuracies of σ_0 measurements and the geophysical model function are key factors in determining the accuracy of the retrieved wind velocity.

Estimation of wind velocity from σ_0 measurements involves inversion of the geophysical model function. However, due to the sinusoidal wind-direction dependence of the geophysical model function, a minimum of three measurements from three different azimuth angles at a given surface spot are required to unambiguously retrieve the wind speed and direction. For NSCAT, three antenna beams with different azimuth angles as shown in Fig. 1 are used. A high resolution in along-beam direction is achieved by Doppler-processing the return ethos using an on-board digital processor. Key NSCAT system papameters are given in Table 1.

Fig. 2 illustrates the functional block diagram of NSCAT. There are four major subsystems: Radio-Frequency Subsystem (RFS), Antenna Subsystem, Digital subsystem (DSS) and Mechanical/Thermal Subsystem (MTS). The function of RFS is to generate the transmit pulses and route them to the antenna subsystem through a waveguide-switch matrix to the selected antenna beam; to receive the return signal, down-convert

S/C Altitude	796.75 at equator
S/C Orbit	Sun-synchronous 41 days repeat 10:30 am equator crossing at descending node 98.59” inclination
Swath	450 Km on each side of S/C subtrack
Coverage	90% of oceans every 48 hours
Resolution	cm-cell: 25 Km Wind vector cell: 50 Km
Frequency	13.995 GHz
Antenna polarization	6 V-pol, 2 H-pol
Antenna beam width	28” (3-dB broad beam) 0.41° (3-dB narrow beam)
Antenna peak gain	34.2 dB (V-pol), 33.4 dB (H-pol)
Mass	300 Kg
C power	275 W
Peak transmit power	110 W
Pulse width	5 ms
Pulse repetition frequency	62 Hz

Table I
NSCAT key parameters.

and pass the signal to the DSS; and to calibrate receiver gain using a noise source, A temperature-compensated stable local oscillator (STALO) at 49.98 MHz and two LO’s at 249.91 and 946.66 MHz are used to generate the 13.995 GHz transmit frequency. The transmit signal is interrupted continuous waves with a pulse length of 5 ms and a pulse repetition frequency (PRF) of approximately 62 Hz. The transmit signal is amplified by a high voltage traveling wave tube amplifier (TWTA). The received signals are down-converted and passed through four crystal filters, and further downconverted to baseband before inputs to the DSS.

The NSCAT antenna subsystem consists of six identical, dual-polarization fan beam antennas. Each antenna is made up of two separate slotted waveguide arrays. While all the antennas are dual-polarized, only the vertical polarization is used for antennas 1, 3, 4, and 6. To achieve the desired fan beam illumination pattern on the earth surface, the antennas are 10 ft long, 2.5 in wide, and 4 in deep. The antennaa are comprised of graphite-epoxy horns and thin-wall aluminum waveguides. Consequently, the antennas produce a fan beam with a 28° beamwidth in elevation (along-beam) and a beam width of 0.4° in azimuth (cross-beam). MTS provides antenna stow and deployment mechanisms and the structural support for the RFS and DSS. It also provides a stable thermal environment to maintain the instrument in the operational temperature via a passive control scheme (louver).

NSCAT will be the first spaceborne scatterometer to utilize on-board digital Doppler processing. Ths DSS consists of two processors: a command and control processor (CP) and a digital Doppler processor (DDP). The CP performs the control functions for instrument operations, including receiving commands from the spacecraft, collecting housekeeping and downlink telemetry. In addition, the CP also computes certain processing Parameters for the Doppler processor. The use of the onboard DDP is to reduce the data rate, to improve the c-registration accuracy of signals from three antenna beams, and to allow accurate calibration of the backscattered power measurements.

A. SYSTEM INTEGRATION AND TESTS

The flight subsystems were completed and delivered in 1992. Subsequently, integration tests were performed to check out the functional performance of integrated RFS and DSS on the command and data handling. Additionally, there were calibration tests performed in a thermal-vacuum chamber to characterize the stability and thermal dependence of key RFS and Antenna subsystem components, including the transmit power monitor, TWTA, noise source, receiver gain, RFS and DSS spurs, and antenna gain and squint angles. The tests concluded that the flight instrument achieved a calibration stability of 0.3 dB, far exceeding the required performance of 0.57 dB. The flight system was shipped to Japan in September 1994 and is currently being integrated with the ADEOS spacecraft.

B. NSCAT SCIENCE DATA PRODUCTS

The other major system of NSCAT is the ground data processing system. Ground data processing system will produce wind measurements within 2 weeks of receiving raw NSCAT data from the ADEOS spacecraft throughout the three-year mission. Arrangements are being made to allow near-real-time access to these wind data by agencies such as the National Oceanic and Atmospheric Administration. NSCAT data products will include global backscatter data, 50-Km resolution ocean wind vectors in the measurement swaths, and spatially and temporally averaged, gridded, wind field maps.

NSCAT FUNCTIONAL BLOCK DIAGRAM

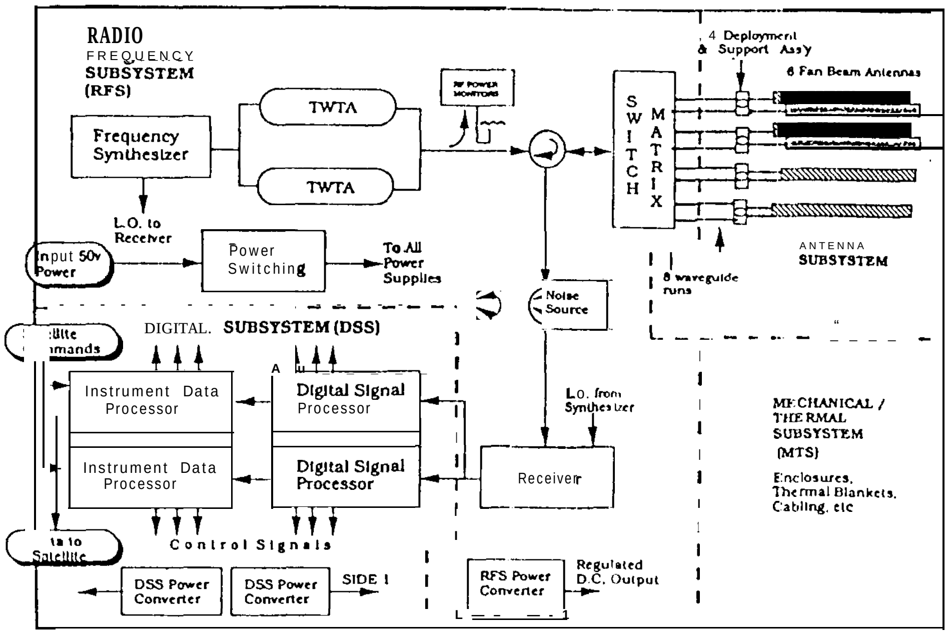

Figure 2. NSCAT functional block diagram

III. SEAWINDS - A FOLLOW-ON MISSION

The Earth Observing system (EOS) scatterometer called SeaWinds will measure ocean surface wind speeds and directions. The EOS program is developing a number of instruments and platforms designed to address global environmental change. As a follow on to NSCAT, data from SeaWinds will play a crucial role in interdisciplinary scientific investigations of the global weather patterns and climate systems. In a major change from its predecessor NSCAT, SeaWinds will use a dish antenna with two beams in place of NSCAT'S array of six, 3-meter long antennas. As the dish antenna is rotated about the satellite nadir axis at 18 rpm, it radiates microwaves pulses at a frequency of 13.4 GHz across broad regions on Earth's surface. SeaWinds will collect data in a continuous band 1800 Km wide and will not have a gap along the satellite track as NSCAT does.

The flight instrument is comprised of three major subsystems, including SeaWinds Electronics Subsystem (SES), Antenna Subsystem (SAS), and Command and Data subsystem (CDS). Development of these subsystems are underway and will be integrated and tested at the Jet Propulsion Laboratory in 1997.

The EOS Data and Information System (EOSDIS) ground computers will produce global wind measurements within 48 hours after receiving the raw data from the spacecraft, with no backlog, throughout the mission. Arrangements will be made to provide near-real-time access to raw SeaWinds data by operational meteorological agencies.

IV. SUMMARY

This paper summarizes the NASA scatterometers being developed by the Jet Propulsion Laboratory for global ocean wind measurements. The instrument development status of NSCAT is presented together with the expected science data products. A follow-on NASA mission, SeaWinds, is also described.

ACKNOWLEDGMENTS

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